Semiconductor Manufacturing in Japan

Dataquest Conference, Phoenix, 1981
Invited Speech

Commentary

This conference, hosted by Dataquest, was the largest at that time as a semiconductor-related conference, and was held for three days from October 14 to 16 in 1981. In this conference, eminent figures in the leadership position of the semiconductor industry were present including Intel's Robert Noyce, AMD's Jerry Sanders, and Motorola's Gary Tooker. It was the first presentation I made at an international conference; my debut game, so to speak. It still remains in my mind as an unforgettable memory.

It can be said that Japan - US semiconductor friction started substantially in this year of 1981. In March of this year, Gene Bylinsky, a magazine-writer wrote a sensational article titled "The Japanese Chip Challenge" in Fortune magazine in the United States. In this period, the 64K bit DRAM generation started to rise and Japanese makers were dominating the market. The basic tone of the article was like this: "If the US loses to Japan in the 64K DRAM competition, the risk is not only limited to the semiconductor industry, but it is also for the computer industry which is much larger than semiconductor."
In the autumn of this year, an industry research company reported that Japan acquired 70% of market share with 64 Kbit DRAM, and among them Hitachi took 30% of the world share. In such circumstances, I was the only person invited from Japan to make a speech. It was on the most delicate theme in the situation surrounded by all enemies so to speak.

Based on the background of the time, I described the characteristics of semiconductor manufacturing in Japan, quoting examples as familiar as possible. Beginning with the geographical setting in which Japan was placed, I touched on the characteristic features of the Japanese market (consumer field orientation), the technology (strong orientation to lower power, and leading with high speed CMOS) and so on. I then introduced annual events and small group activities which were somewhat special to Japan, and then emphasized the importance of education.

An important message I provided in this lecture was that "the future mainstream of semiconductors will shift from NMOS to CMOS". There were many questions from the executives who were familiar with the technology such as, "performance is amazing but how about the manufacturability?“. I think, however, it gave a strong impression as a whole.
In conclusion, I sent a cheering message that, "The US is in the top position by far in the semiconductor industry, and particularly strong in the microprocessor field.” I told that Japan was demonstrating the strength in the manufacturing of microfabrication products, in which team works nurtured by small group activities were playing important roles, and emphasized the importance of education to cope with the extremely fast technological advancement in semiconductor industry.

Nielsen Dataquest

SEMICONDUCTOR MANUFACTURING IN JAPAN

Dr. Tsugio Makimoto
Deputy General Manager Musashi Works
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Dr. Makimoto is a Deputy General Manager of Musashi Works, Semiconductor and IC Division, Hitachi Ltd., with responsibility for all MOS engineering departments. Since joining Hitachi in 1959, he has been engaged in semiconductor device engineering and manufacturing. In 1968 Dr. Makimoto was promoted to Senior Engineer in the Integrated Circuit Engineering Department, where he developed several MOS logic devices for calculators and watches. Dr. Makimoto received a B.S. in Applied Physics and a Ph.D. in Electrical Engineering from the University of Toyko, and an M.S. degree in Electrical Engineering from Stanford University.

DATAQUEST, Inc.
SEMICONDUCTOR INDUSTRY CONFERENCE
October 14, 15, and 16, 1981
Phoenix, Arizona

This speech was given by the invitation from Dataquest. My post at that time was the Deputy General Manager of Musashi Works of Hitachi, Ltd., to be responsible for overseeing the all technical departments of MOS products in general.

It was in the midst of the Japan-U.S. semiconductor friction at this time, and I had to be careful about this point, too.

SOME ASPECTS OF SEMICONDUCTOR MANUFACTURING IN JAPAN

Tsugio Makimoto
Musashi Works, Hitachi Ltd.

1. Geographical Setting

Japan is a small, isolated country consisting of four major islands, namely, Hokkaido, Honshu, Shikoku, and Kyushu. If Japan were an American state, it would rank fifth in geographical size, following Alaska, Texas, California, and Montana.

Land space is roughly 1/30 of that of America, and population of 115 million is roughly half the size of America, making Japan the most densely populated country in the world. Population density is about 300 people per square km which is roughly 15 times that of America.

Natural resources are limited and Japan has to depend on imports for most of its raw materials and energy resources.

Typhoons, volcanic eruptions and earth-quakes are typical examples of natural catastrophes which seem to have affected the mentality of the Japanese during their long history, so it is sometimes called "typhoon mentality".

Fig.1 shows a semiconductor map of Japan indicating production facilities of Japan-based and U.S-based companies.

2. Semiconductor Market

In the past several years, the semiconductor market structure in Japan has been gradually and steadily changing (Fig.2).

Up to the early 70's, consumer sectors such as TV's, Audio's, Caluculators, and Watches shared the major portion. But the trend is shifting toward higher share of computer and industrial sectors. However, new consumer sectors such as VTR, is increasing at a rapid growth rate and is now becoming a major part of the consumer field.

Memories, Microprocessors, and Standard Logic Circuits are major components for computer and industrial sectors. Recently, however, strong demand and interest are emerging for the introduction of gate arrays for improving performances, packaging density, reliability, and cost of systems.

For new consumer sector such as VTR, bipolar linear IC's and discrete devices, are major components. There is a steady trend, however, for more and more MOS devices to be introduced for the

First of all, I touch on the characteristic features of Japan such as geographical setting and natural disasters. Japan's land area is about 1/30 of the US, the population about 1/2, and the population density about 15 times higher. Many natural disasters such as earthquakes, typhoons, volcanic eruptions etc. have affected the mentality of the Japanese people.

The Japanese semiconductor market grew mainly in consumer applications, however the proportion of computers and industry sectors is gradually increasing.

sophistication of equipment.

Fig.3 compares the market structure of Japan and America.

3. Semiconductor Technology

Technology development has a strong relationship with market structure. In other words, the market is a strong pulling force for technology.

Up to the early 70's, the pulling forces or locomotives were calculators and watches for MOS LSI's, and TV's and Audio's for Bipolar IC's.

In the case of calculators, for example, essential requirements by calculator manufacturers were for high volume, low cost, high reliability production techniques because of the very competitive nature of the products. Also, in relation to product development, high density and low power circuits were permanent requirements from customers.

This led to the development of high density C-MOS circuits which are now applied to memories and microprocessors (Fig.4).

Fig.5 shows the trend of the evolution of fine pattern technology.

Fig.6 is the classification of MOS device technology with typical vehicles of technological development. The next target of development will be 2μm technology with vehicles of 256K Dynamic RAM and 64K Static RAM.

Fig.7 shows evolution of MOS device technology, and it's dramatic changes in the past five years.

4. Annual Events

A New Year in Japan starts with "Hatsumode" which is literally the first celebration of the year at a shrine (Fig.8). It is not unusual for a factory of a company to have its own shrine on its premises. People wish for longevity, prosperity, safety, and sometimes, for passing examinations (Fig.9).

The fiscal year as well as the school year starts in April. Prior to the start of the new fiscal year, a new budget has to be fixed. Budget making is a fairly lengthy procedure, occupying a couple of months. Challenging targets are set for the activities of the next six months. The first budget period, which is called "KAMI", ends in September, and the next period of "SHIMO" starts in October.

The month of December is for "Bonenkai" which literally means Forgetting-the-last-year party. The highlight of the year is the ceremony of awarding prizes for outstanding performances by staff members during the past year.

Technological development and market structure are closely related. In the early 1970s, watches and calculators were the main drivers in MOS, and TVs and VCRs in bipolar. For watches and calculators, low cost, low power, and high reliability were required, which led to the development of highly integrated CMOS, which then spread to memories and microprocessors.

Then I touched on annual events in Japanese business activities; starting from “Hatsumode” in January (practice of visiting shrines) to year-end parties in December.

5. Circle Activities

Circle Activities in Japan date back to the early 60's when Nippon-Kokan started a so-called "QC circle" in 1961, followed by NEC with their "Zero Defect Movement" in 1965 (Fig.10). This kind of movement was first initiated by American industries rather than by Japanese. QC Movement in American industry dates back to 1951 which was 10 years earlier than the first Japanese movement.

Today, however, the circle activities have become established in Japan and are regarded as important factors for quality and productivity improvements. The wide spread distribution of the movement can be attributed to many factors including homogeneity of society, uniformity of education level, life-time employment, and loyality to the company.

Hitachi has the largest number of suggested improvements from employees with 4,220 thousand suggestions in 1980 (Fig.11). Hitachi-Koki, a subsidiary company of Hitachi, achieved the highest suggestions per person, with 157 in 1980.

The highest number of suggestions made by a single person in 1980 is reported to be 6,919 by Mr. Ueda of Matsushita Electric Industrial Co, Ltd.. This is a tremendous number taking into account the days in a year.

The purpose of Activities is summarized in Fig.12. For pormoting these activities, slogans or mottos are selected and displayed on posters or badges. A couple of examples of suggestions made by workers at Hitachi Musashi are shown in Fig.13.

6. Education

The importance of education can never be over-stated for those who are engaged in semiconductor manufacturing.

The reasons include ;

1) One of limiting factors of growth is the availability of trained engineers.
2) College education is oriented toward basic principles, so industries have to prepare education programs for their own special needs.
3) Technology is in a state of "revolution" which means that new technology at any one time becomes obsolete in a very short period.

Fig.14 shows trains of "technology waves", intervals of which is about five to ten years.

The Small Group Activity which originally started in the US in the 1950s, and has settled itself in Japan is explained with some actual examples. This activity is playing an important role in the Japanese industry. The importance of education can never be emphasized too much, and some examples are presented.

The school system in Japan is very similar to that of America. About 90 percent of people go to highschool which contributes to a high level of education for the direct workers. It is estimated that 35 to 40 percent of high-school graduates go to colleges.

Education programs in industry are very important from practical view-points. Fig.15 shows an example of the program in a company. Two years after joining the company are considered to be a "training period" and all freshmen have to go through the following program ;

1) Direct line work for 9 months.
2) Fire fighting training, a total of 40 hours.
3) Computer programming, a total of 200 hours.
4) Introductory Engineering course, including semiconductor physics, device theory, design, manufacturing and application, a total of 130 hours.
5) An English conversation program is provided as an option, but a qualification test has to be taken by all.
6) The highlight of the program is the paper preparation and presentation which will be critically reviewed by several managers from various view-points.

After the two year training period, many programs are prepared for engineers and managers depending on their needs. Although some programs are provided at each factory, corporate level education is also active. Hitachi has several institutions dedicated to education in various specialized fields.

7. Concluding Remarks

One of the significant differences between Japan and America is the geographical settings which have effects on shaping Japanese and Americans. It is sometimes argued that Japanese are good at thinking small, and Americans are good at thinking big.

Today, America is definitely at the position of No. 1 in semiconductor industries. Especially in the case of "big" items such as 16 bit or 32 bit microprocessors, Americans have demonstrated their strength in product definition and system engineering.

Recently, Japan has demonstrated its strength in productivity and quality of "small"-geometry products, such as memories. This is related to various factors such as market background, historical trend of technology, and employee movement such as circle activities.

The education of new college graduate employees is introduced with Hitachi's examples.

As a conclusion, the influence of geographical setting on the differences in mentality between Japan and the United States was pointed out. Strength of the US was commented; "US is by far the No. 1 in the semiconductor industry, especially in the field of microprocessors." Japan's strength is in the manufacturing of microfabrication products, owing to market background, trends in technology development, and Small Group Activities, etc.

Figures and explanations follow.

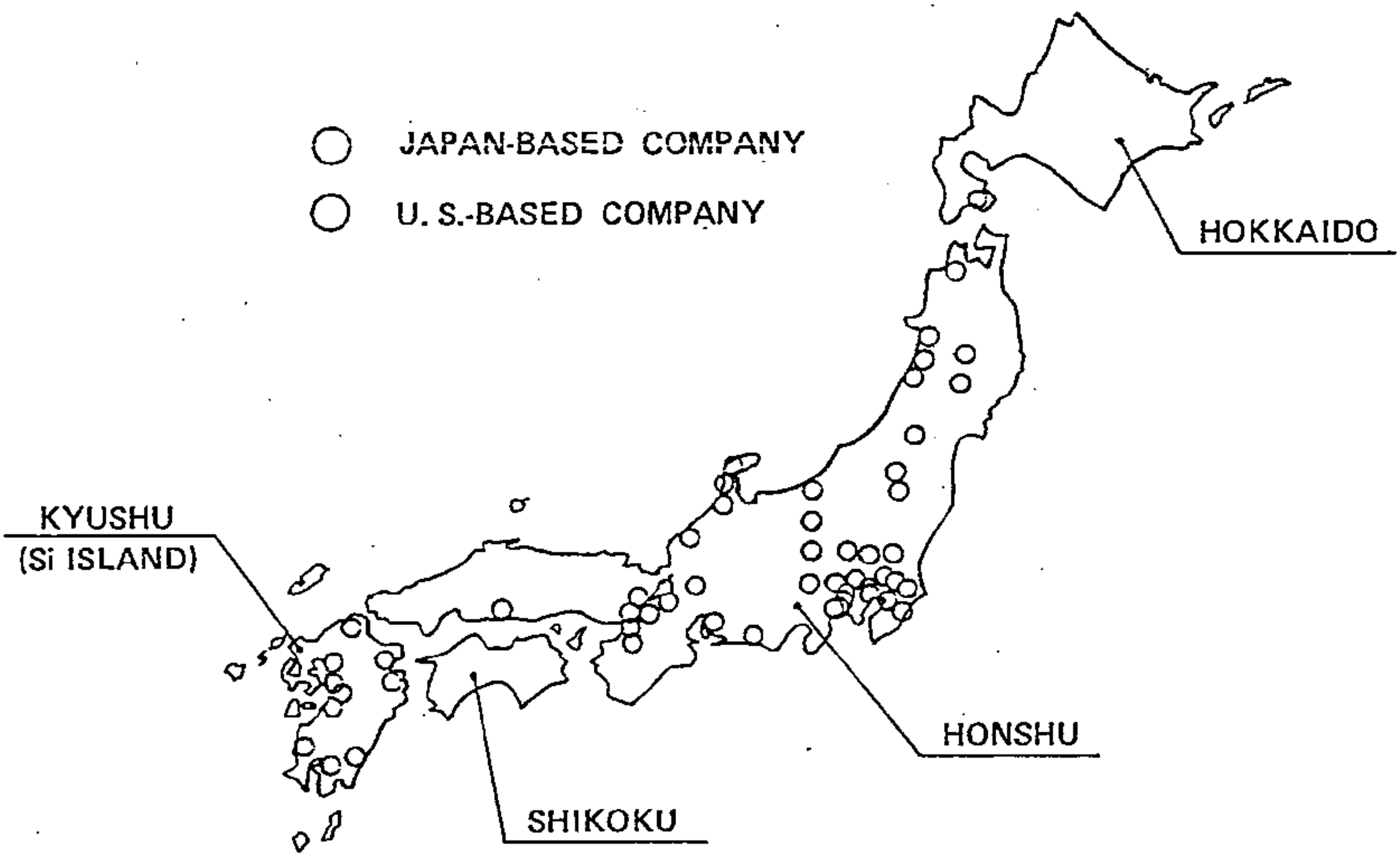


Fig. 1 SEMICONDUCTOR MAP OF JAPAN

The Figure shows locations of semiconductor factories in Japan. Many factories are concentrated in Kyushu Island, and it is also called "Silicon Island". As one of its backgrounds, Kyushu has abundance of good water, as is shown by its good Shochu liquor for which clean water is indispensable. Semiconductor manufacturing requires abundance of good water, too.

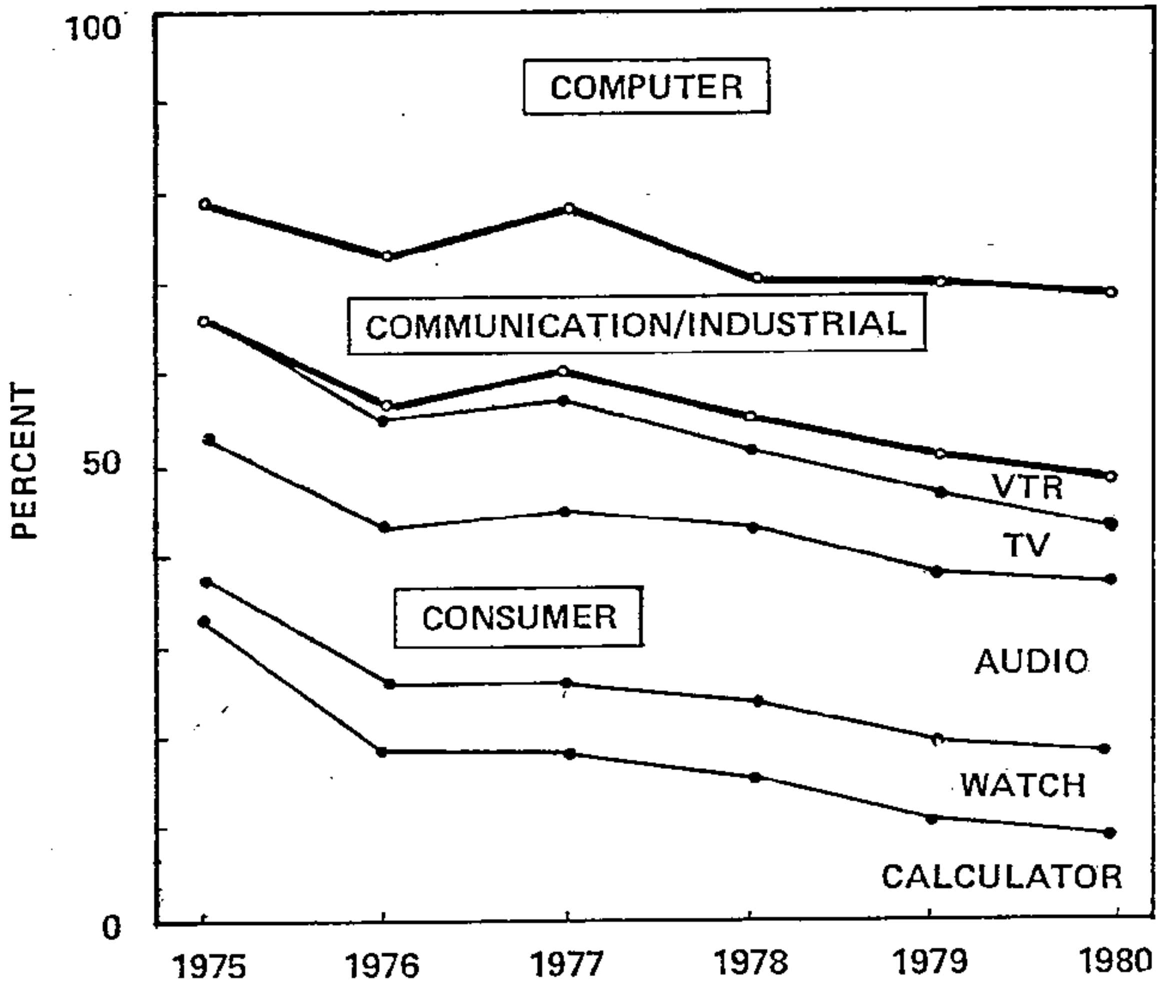
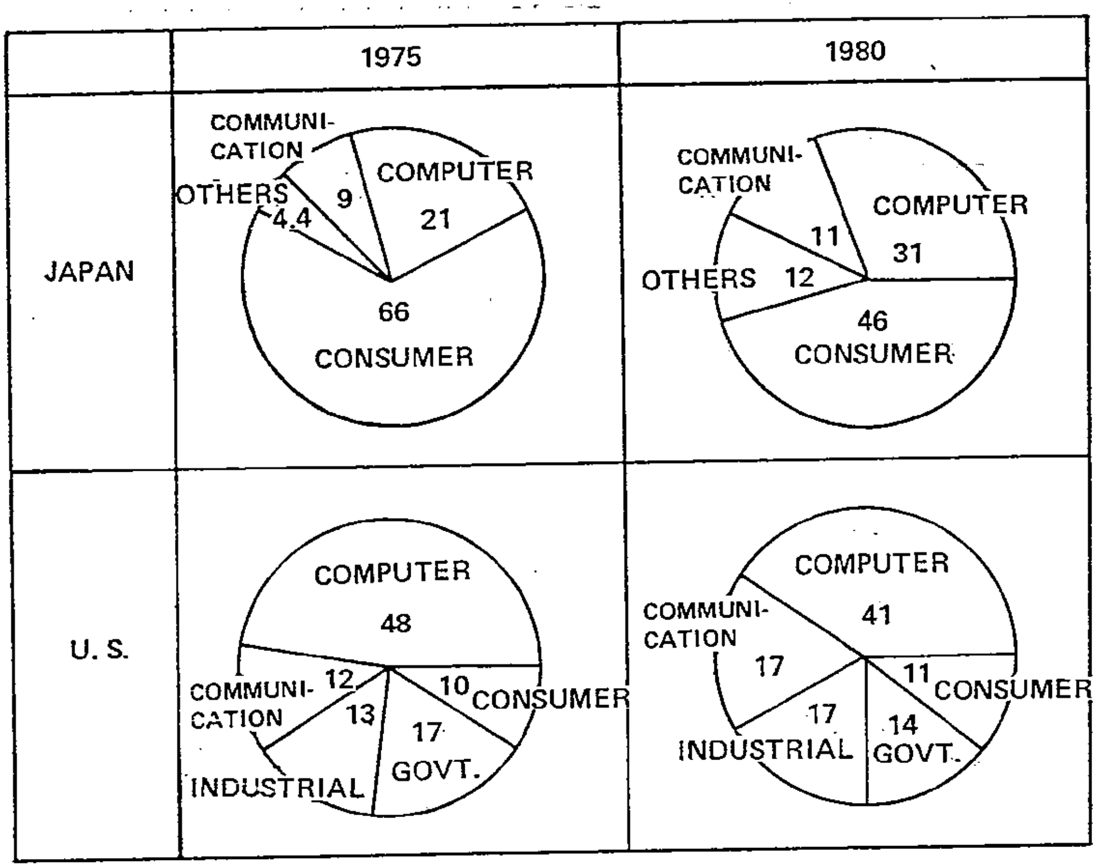


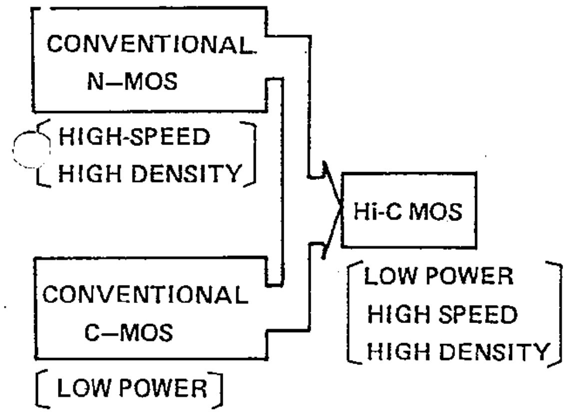
Fig. 2 TREND OF IC MARKET IN JAPAN

It shows the trend of Japanese semiconductor market. In 1975, calculators and consumer sectors shared large portion, but the proportion of computers, communications, and industries started to increase in 1980. In the consumer field, TV market has shrunk, and VCR market has grown.



F COMPARISON OF IC MARKET BETWEEN JAPAN AND U. S.

The comparison of the market structure between Japan and the US is shown. As of 1975, the largest market in Japan was the consumer field, and it was the computer market in the US. In 1980, the proportion of computers has risen in Japan, and the growth of communication field became prominent in the US.



TYPE / ITEM	4^k S-RAM	16^k S-RAM	
	HM6147H	HM6116	HM6167
ORGANIZ-ATION	$4^k \times 1$	$2^k \times 8$	$16^k \times 1$
PROCESS	Hi-C MOS (H SERIES)	Hi-C MOS	Hi-C MOS
	DOUBLE POLY	SINGLE POLY	DOUBLE POLY
PIN OUT	18 PIN 300mil STANDARD	24 PIN 600 mil STANDARD	20 PIN 300 mil STANDARD
ACCESS TIME	35/45 nS	120/150/200 nS	70/85/100 nS
OP-POWER	150 mW	170 mW	150 mW
SB-POWER (V_{IH}=Vcc)	5 μW	10 μW	10 μW
CHIP SIZE	8.9 mm²	26.2 mm²	21.1 mm²
PACKAGE	PLASTIC/CERDIP		

Fig. 4 Hi-C MOS TECHNOLOGY

Introduction of high-speed CMOS technology (Hi-CMOS) developed by Hitachi. It was the highlight of the speech this time. In those days, CMOS was considered as niche technology for low power applications. Hitachi challenged this industry consensus and developed innovative high-speed CMOS technology, and applied it to 4K /16K SRAM. CMOS outperformed NMOS for the first time. It gave a strong impression to the audience with many questions after the speech.

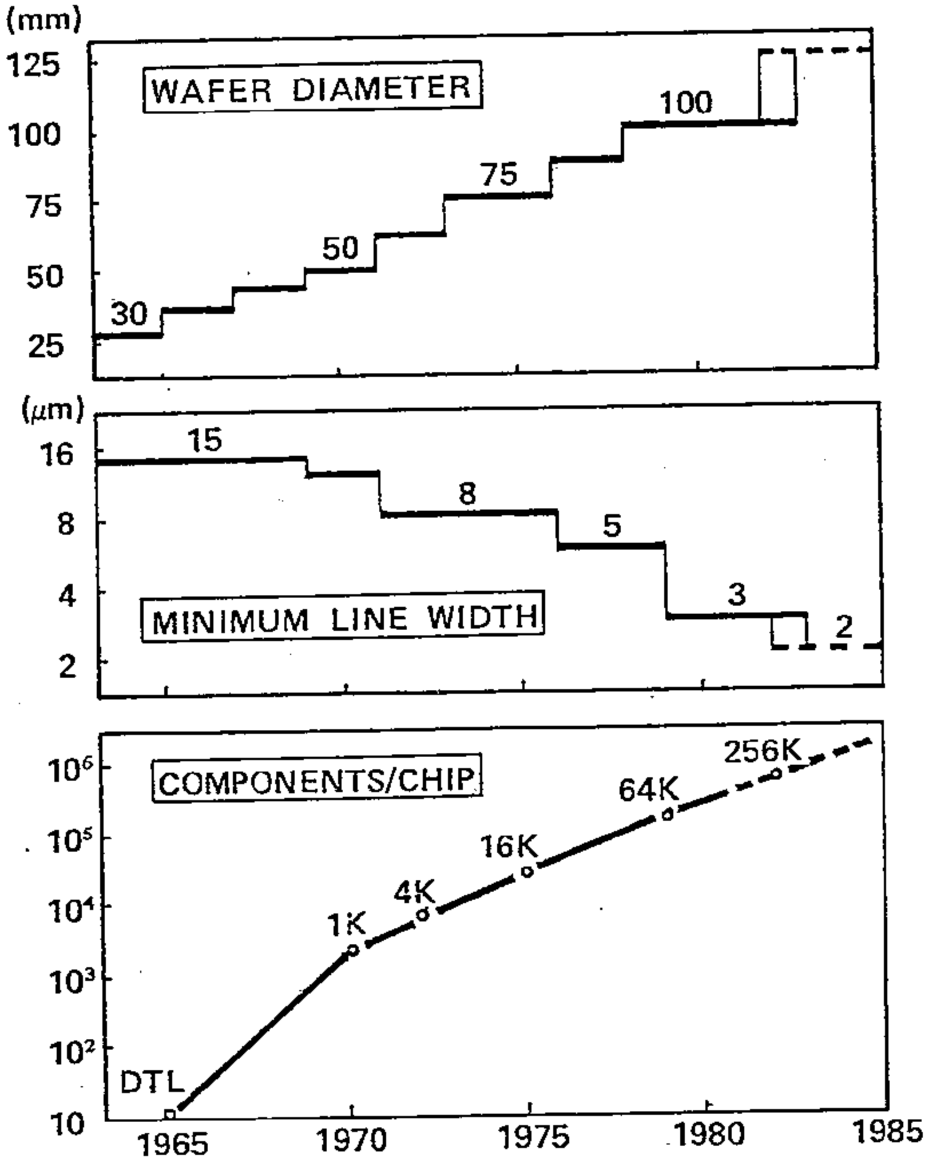


Fig. 5 TRENDS OF SEMICONDUCTOR TECHNOLOGY

The cutting edge technology at the time was with the wafer diameter of 100 mm, processing level in 3 μ, and the DRAM integration level was 64 Kbits. The prediction for 1985 was the wafer diameter of 125 mm, the processing level of 2 μ, and the DRAM integration level of 256 Kbits.

TIME / BASIC DIMENSION / CHANNEL TYPE	PAST	PRESENT		FUTURE
	8 μm	5 μm	3 μm	2 μm
P-MOS	CALCULATORS	CALCULATORS 4 BIT MPU'S		
N-MOS	MEMORIES (4k DYNAMIC)	MEMORIES (16k DYNAMIC 4k STATIC) 8 BIT MPU'S	MEMORIES (64k DYNAMIC) 16 BIT MPU'S	MEMORIES (256k DYNAMIC)
C-MOS	WATCHES	CALCULATORS WATCHES MEMORIES (4k STATIC) 4 BIT MPU'S	MEMORIES (4k STATIC 16k STATIC) 8 BIT MPU'S	MEMORIES (64k STATIC)

Fig. 6 MOS DEVICE TECHNOLOGY

This table shows the past and present situations, and the future prospect for MOS device types; PMOS, NMOS, and CMOS. PMOS ends in the 5 μ era. NMOS leads its way to 2 μ DRAM (256 K). CMOS was used for watches and calculators in the past, and it started to be used for SRAM from the 3 μ era, and it will be used for 64Kbit SRAM in 2 μ era. It was a novel and drastic assertion at this time that high speed devices would also shift from NMOS to CMOS in the future.

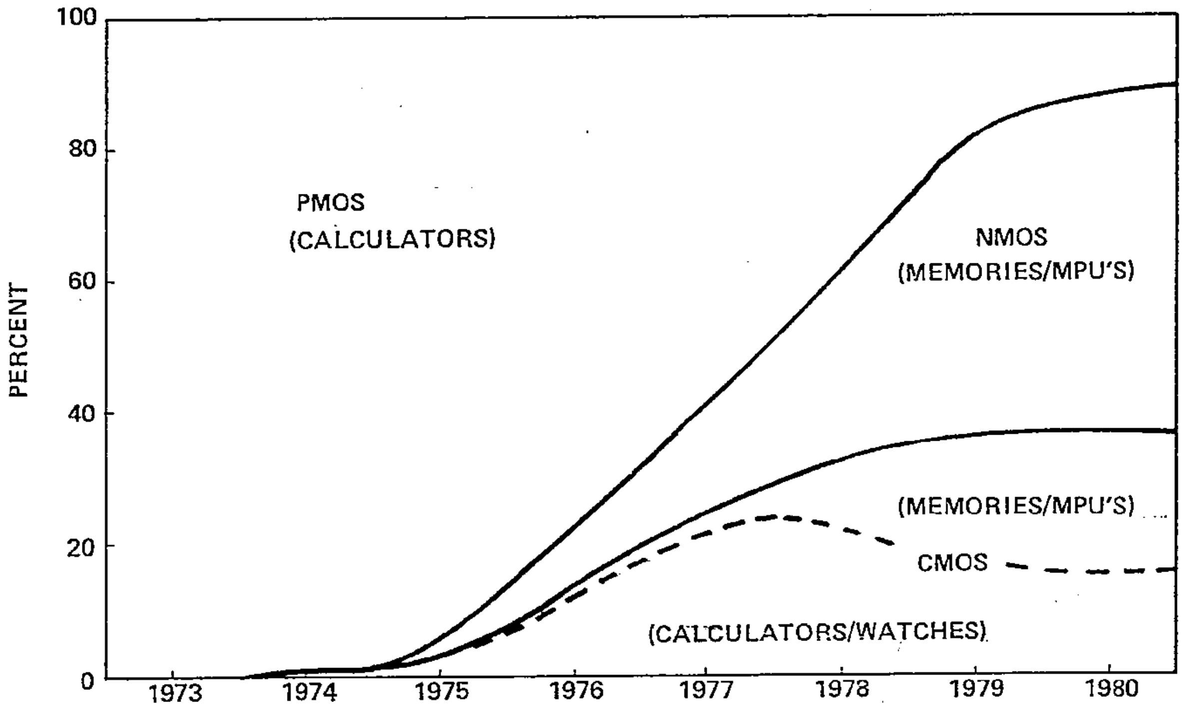


Fig. 7 EVOLUTION OF MOS DEVICE TECHNOLOGY

The rise and fall of MOS devices are shown. Up to 1975, PMOS for calculators occupied an overwhelming share, but its share gradually decreased, and NMOS and CMOS grew. In CMOS, the ratio of memory and microprocessor has been increasing in place of calculators and watches which shared the major portion.

MONTH		GENERAL	SHOW & CONFERENCE	INTERNAL
SHIMO	JAN.	• NEW YEAR'S DAY	INTERNEPCON/JAPAN	NEW YEAR PARTY
	FEB.	• DOLL FEAST	INFORMATION PROCESSING SOCIETY CONF.	BUDGET PLANNING ⇦ ORGANIZATION CHANGE
	MAR.	• COMMENCEMENT		
KAMI	APR.	ENTRANCE CEREMONY CHERRY BLOSSOM	IECEJ* CONF.	⇦ FRESHMEN JOIN "SHUNTO"
	MAY	• CHILDREN'S DAY	MICROCOMPUTER SHOW	MMM PICNIC
	JUNE	RAINY SEASON		
	JULY	• FIRE WORKS FESTIVAL		BUDGET PLANNING ⇦ ORGANIZATION CHANGE
	AUG.	"OBON"	SOLID-STATE DEVICE CONF.	
	SEP.	TYPHOON SEASON		
SHIMO	OCT.	CHRYSANTHEMUM FESTIVAL	ELECTRONICS SHOW DATA SHOW	• SPORTS DAY
	NOV.			
	DEC.	• X'MAS		• ANNUAL AWARD YEAR-END PARTY

* IECEJ: INSTITUTE OF ELECTRONICS AND COMMUNICATION ENGINEERS OF JAPAN

Fig. 8 TYPICAL SEMICONDUCTOR CALENDAR OF A YEAR

National events are shown on the left side, semiconductor-related shows and conferences in the center, and internal activities are shown on the right side. MMM was the slogan of Small Group Activities in Hitachi intended to eliminate three bad M's; Muri (unreasonable deed), Muda (waste), and Mura (unevenness).

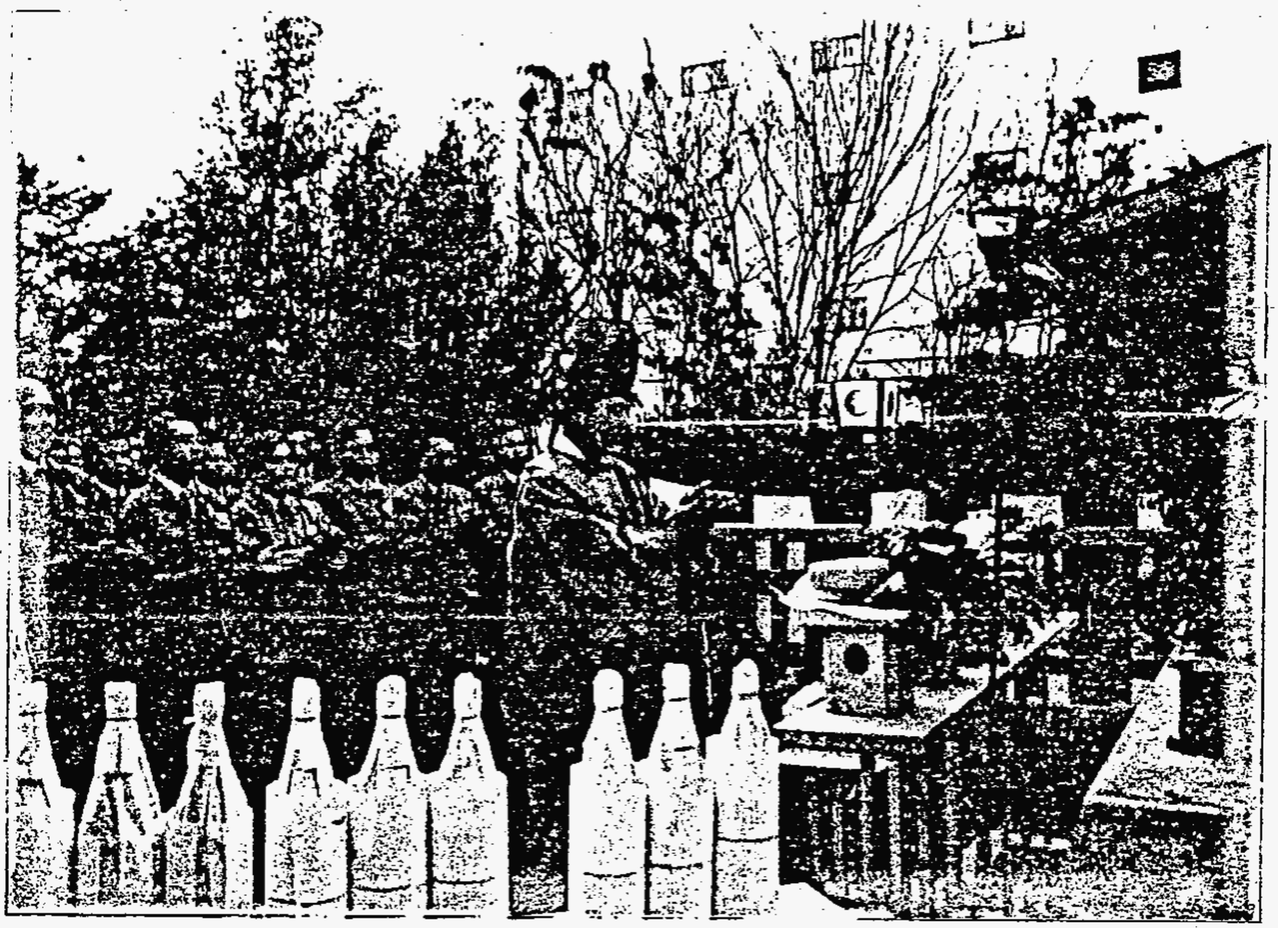


Fig. 9 "HATSUMODE" AT A SHRINE ON THE FIRST DAY OF THE YEAR

A ceremony of "Hatsumode" held on New Year's Day every year. Employees visit a shrine, purify themselves first and pray to God for safety and prosperity. This is an extremely Japanese-style event, and it may not have been clearly understood by the audience. I am afraid that many of them felt rather strange.

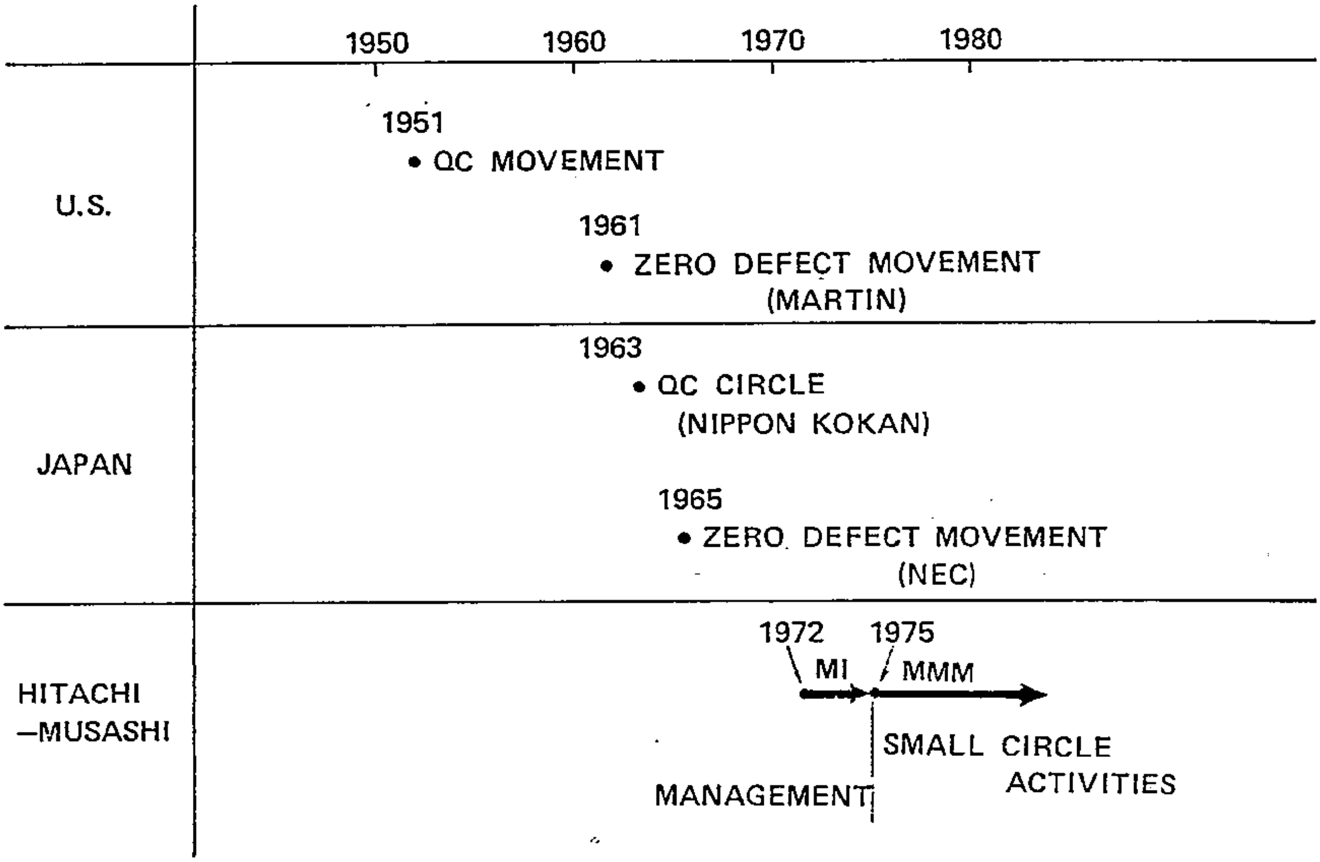


Fig. 10 **HISTORY OF CIRCLE ACTIVITIES**

The Small Circle Activities first started in the United States in the 1950s, and then spread to Japan in the 1960s, and settled there. It was started in 1972 in Hitachi's semiconductor operation. Initially it was started as MI (Management Improvement) movement, then was developed into MMM activities in the next phase intended to eliminate three bad M's (Muri, Muda, and Mura).

A. TOTAL SUGGESTIONS (UNIT: THOUSANDS/YEAR)

1.	HITACHI	4,220
2.	MATSUSHITA	2,610
3.	FUJI-DENKI	1,680
4.	TOYO-KOGYO	1,350
5.	NISSAN	1,270

B. SUGGESTIONS PER PERSON (UNIT: NUMBER/YEAR)

1.	HITACHI-KOKI	157
2.	FUJI-DENKI	154
3.	ENZAN-FUJI	138
4.	SUMITOMO RUBBER	95
5.	AISHIN WARNER	81
6.	HITACHI	75

Fig. 11 NUMBER OF SUGGESTIONS IN 1980

The list A shows the number of company wise annual proposals (in thousands), and the list B shows the number of annual proposals per employee, both in 1980. In Hitachi, 4.2 million cases were proposed annually, and 2.61 million cases in Matsushita (now, Panasonic). Surprised voices were heard among the audience to the size of such numbers, but we also have similar feeling today (as of 2018).

1) TO ATTACK ANY PROBLEMS PRESENT AT WORK SHOPS BY PARTICIPATION OF ALL MEMBERS CONCERNED

2) TO CONTRIBUTE TO QUALITY IMPROVEMENT, COST REDUCTION, OVERALL EFFECTIVENESS, SHORTER LEAD-TIME, AND SAFETY

3) TO BE INTENDED TO BRUSH-UP ONE'S ABILITY AND PERSONALITY THROUGH THE ACTIVITIES

Fig. 12 PURPOSE OF SMALL CIRCLE ACTIVITIES

This is to summarize the purpose of Small Circle Activities.

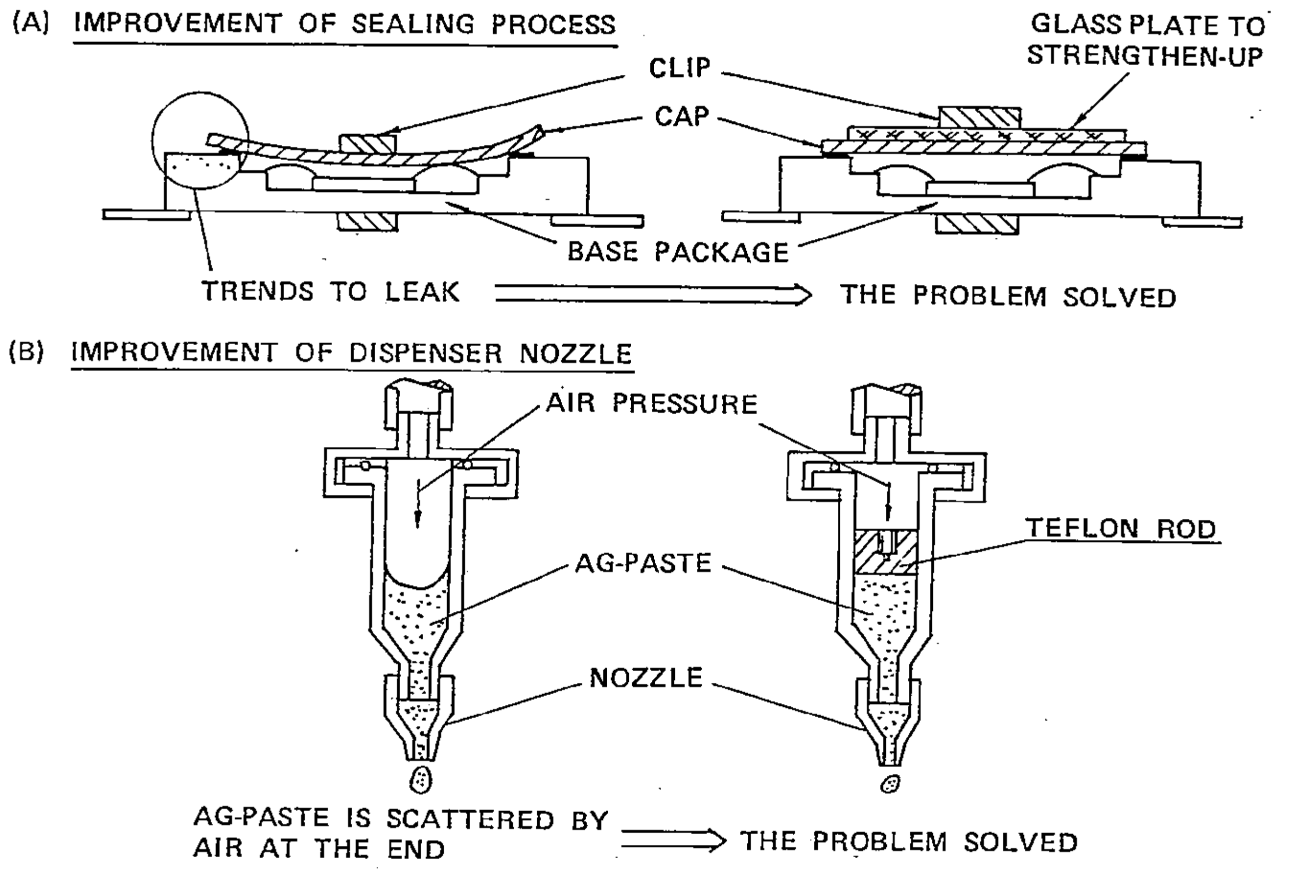


Fig. 13 EXAMPLES OF SUGGESTIONS

Two examples of semiconductor related proposals are shown. These are the cases which realized actual effects.

A) In order to eliminate the leakage, a glass plate is applied to strengthen the cap.

B) A Teflon rod is used to prevent silver paste from scattering at the last part.

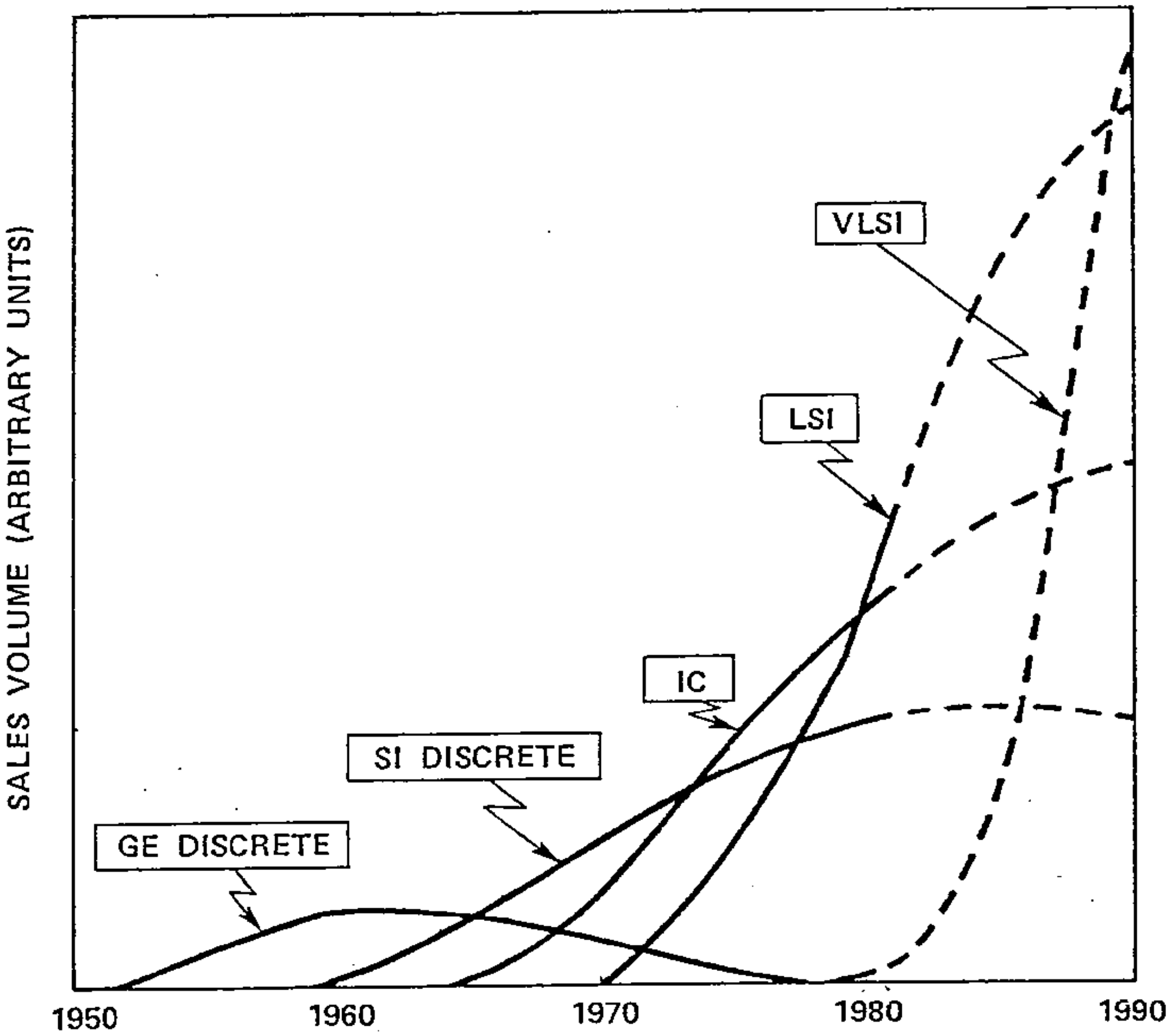


Fig. 14 TRAINS OF "TECHNOLOGY WAVES"

Wavy transitions of semiconductor technology are shown here. The figure shows how intense technological innovation occurs in this field. A new wave rises every five to ten years, overtaking the previous wave. In other words, technology becomes obsolete at such a pace in the semiconductor field. Prediction was made that VLSI would be the biggest segment after 10 years in 1990.

This concept was repeatedly introduced in the later speeches including Keynote at IEDM in 1982.

YEARS AFTER ENTRANCE	EDUCATION PROGRAMS	DURATION	COMMENTS
0 ~ 1	• LINE WORK EXPERIENCE • FIRE FIGHTING TRAINING	9 MONTHS 40 HRS	ALL ALL
1 ~ 2	• INTRODUCTORY ENGINEERING COURSE • COMPUTER PROGRAMMING • IN-COMPANY EXAM FOR ENGLISH • RESEARCH REPORT AND PRESENTATION	130 HRS 200 HRS – –	ALL ALL ALL ALL
3 ~ 10	• ADVANCED ENGINEERING COURSE (10 PROGRAMS) • INTEGRATED ENGINEERING DEVELOPMENT PROGRAM (CORPORATE PROGRAM) • FOREIGN LANGUAGE COURSE (ENGLISH, FRENCH, GERMAN ETC.) • INTEGRATED MANAGEMENT COURSE	30~50 HRS 600 HRS 90 HRS –	OPTION RECOMMENDATION RECOMMENDATION ALL
10~	• MANAGEMENT TRAINING PROGRAM (MTP) • SECTION MANAGER COURSE • DEPARTMENT MANAGER COURSE	40 HRS 30 HRS 20 HRS	ALL ALL SEC. MGR ALL DEPT. MGR

Fig. 15 EDUCATION PROGRAM FOR ENGINEERS AND MANAGERS

Educational programs for engineers and managers are introduced, taking the case of Hitachi semiconductor as the examples. Strong emphasis was made on the importance of education based on the fact that technology would become obsolete in 5 to 10 years, as shown in the previous slide (Fig.14).

My concluding remark was that "Human resource is the core of semiconductor business".